Application analysis of digital twin technology in power system

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Abstract. In the construction and development of modern society, in order to achieve the goal of double carbon, energy and power should build a digital, intelligent and electrified energy and power system in the transformation and development. According to the current statistical data analysis of China's energy Bureau, in recent years, more and more installed capacity of new energy generation in China, has become the world's second largest power source, while the proportion of non-fossil energy generation is also gradually rising, some scholars predict that in 2050, China's non-fossil energy will account for more than 50%. After understanding the concept of digital twin application technology, this paper mainly studies the application content and main direction of digital twin technology in power system according to the operation status of power system in the new era and the challenges faced by energy development, and then defines the development prospect of digital twin technology application in power system in the future.

Keywords: digital twin technology; Electric power system; Intelligent; Apply.

1. Introducion

In the context of the transformation of energy intelligence and digitalization, according to the development trend of high information and automation, the rational use of advanced technology to improve the energy system and power system, focusing on providing more safe and convenient service functions for system users. After China's social construction put forward the basic goal of carbon peak and carbon neutrality, energy and power enterprises play an important role in the innovation and development of low-carbon environmental protection. The mood power system with new energy as the main body puts forward higher requirements for the safe and stable operation of the grid, full service, and meeting the demand for power load. In order to better meet the demand for new energy consumption, power enterprises should achieve breakthroughs in technological innovation, operation management and institutional mechanisms. In the deep integration of energy revolution and digital revolution, how to build a store-centered smart energy system is the main issue comprehensively discussed in the power industry in the new era.

In 2002, Michael Greaves, a professor at the University of Michigan, proposed the basic concept of digital twin for the first time, which believes that digital twin is a virtual entity and subsystem that can represent the physical device through the data of the physical device in the information space, and this connection is not one-way and static. From the perspective of practical development, the concept of digital twin was first applied in the maintenance and support of American aerospace vehicles, which can establish a real data space model of aircraft in digital space, and can be completely synchronized with the real state of the aircraft through sensors, so that after the flight, according to the existing status of the structure and the previous load data, Comprehensively evaluate whether the aircraft needs maintenance management, so as to judge whether the aircraft can withstand the next flight compound load. Nowadays, there are more and more researches on the concept of digital twin technology, which involves more and more application fields. From the perspective of the design and application of energy and power systems, digital twins can further improve the monitoring level of network platforms and discover abnormal problems in the operation of power systems as soon as possible, which is the basic condition for creating a new

power system architecture. To design and promote the digital twin power grid is to map the physical power grid into the virtual space in a digital way and evolve synchronously by receiving state information from the physical power grid, so as to achieve the work goal of accurate detection of the physical power grid, and feed the final analysis results back to the physical power grid, so as to optimize and adjust the physical power grid system. For example, in the study of the twin environment, some scholars found that by constructing the digital twin simulation station of the substation, flexibly adjusting the inspection service according to the demand, and using the digital twin robot simulation verification to complete the virtual inspection, the operation efficiency and quality of the system can be further improved; Some scholars have also used digital twin technology to provide a new idea for the safety risk management of substations, gradually expanding the monitoring scope inside substations, truly realizing the goal of digital management of the whole life cycle of power grid equipment, and effectively controlling the cost expenditure of the power industry. Therefore, after understanding the current situation of electric power system construction and application, this paper mainly explores the electric power system architecture and application function with digital twin technology as the core according to the basic concept and main content of digital twin technology, and then determines the effective way to apply digital twin technology in the electric power industry from the perspective of practical development.

2. Methods

2.1 Digital Twins

The concept of the twin can be traced back to the Apollo project of the National Aeronautics and Space Administration of the United States. The development of the digital twin is mainly divided into three stages. The embryonic stage of the digital twin refers to the fuzzy concept in 2003 to the initial concept upgrade in 2011. The incubation phase of digital twins refers to the definition of digital twins proposed by NASA in 2012, and the official publication of the first digital twin white paper in 2014; The growth stage of digital twin, from 2014 to the present, the concept of digital twin technology has been rapidly developed at home and abroad, and the field of practical application is more and more extensive. At present, there are many definitions of digital twins in the academic circle, but due to the diversity of physical objects studied, it is difficult to give a unified definition of digital twins. In research and application, targeted digital twin models should be designed according to different physical objects and cooperate with specific modeling strategies and functional requirements.

2.2 System Architecture

The connotation of digital twin power system is very rich, and its application in power system should be optimized and innovated according to the theoretical basis and experimental conclusions proposed by existing scholars. For example, Tao Fei's team at Beihang University proposed a digital twin inaction model in 2019. The overall model includes physical entities, virtual entities, data, services, and interactions between each other, as shown in Figure 2 below:

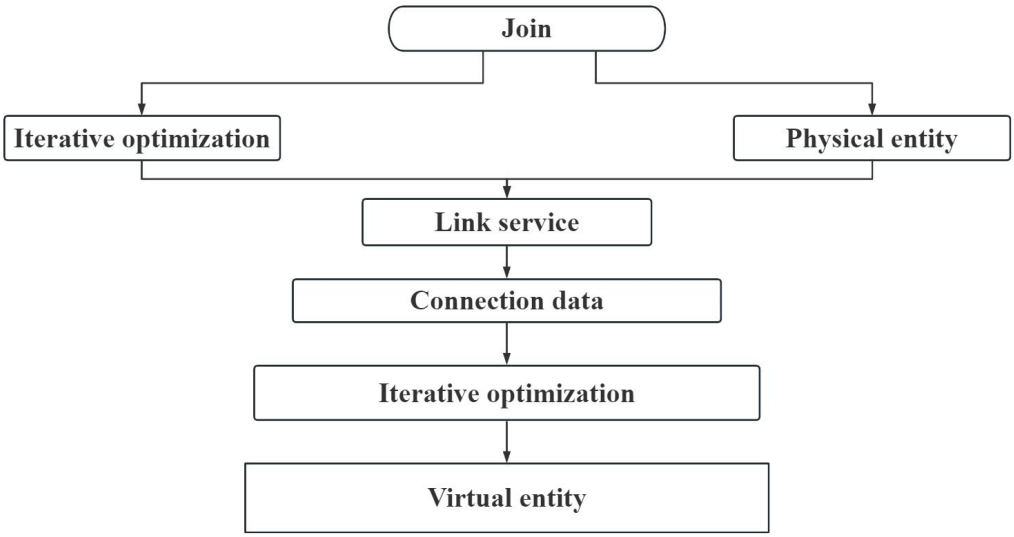

Figure 2 Plot of the five-dimensional model structure of the digital twin

Some scholars from Tsinghua University have proposed that the digital twin is in the process of evolution, and it must have the basic elements such as real space, virtual space, data flow connection and information connection. From the results of the two scholars, The digital twin system of the power grid model is very broad, The core elements and key technologies contained are very important; The China Electric Power Research Institute has also proposed that, The Power Internet of Things is an important technical support for the construction of the digital twin system of the energy Internet, Can provide an intelligent, networked and digital effective carrier for the digital twin system in the virtual space, Make full use of artificial intelligence, network platform, data transmission and other technologies, To complete the physical system of electricity, Real mapping into a digital system; The digital twin technology architecture of power equipment designed by Chongqing University according to the Power Internet of Things, It includes the base layer, data cabin, simulation layer and application layer. By summarizing and analyzing the technical theory of digital twin framework of power equipment and energy network proposed by existing scholars, we can find that although the corresponding technical frameworks are different, they all include multiple modules such as real space, virtual space, data information and service. The specific comparison results are shown in Table 1 below:

Table 1 Comparison results of the existing technical framework of digital twin models

Scholar	Universal framework	Instructions
Tao Fei	Five-dimensional model	A five-dimensional conceptual model suitable for many fields is proposed
Pu Tianjiao	Energy Internet	The platform layer corresponds to virtual entities and data
Liu Yadong	Electric power equipment	The communication layer includes data and connection interactions
Yang Fan	Electric power equipment	The data interaction layer includes data and connection interactions

3. Results analysis

3.1 Experimental design

After understanding the basic concept of digital twin and the application framework in the power system, this paper takes the digital twin heat pump switching control of heat pump refrigeration and heating system in a certain area as an example, and mainly discusses its efficiency and quality in practical application. From the perspective of the practical application, The working idea of this system is divided into the following points: First, By performing a mechanistic modeling of the building heat transfer laws, Because the model parameters of the refrigeration and heating system are more complicated, When creating a system model, To guarantee the accuracy and perfection of the data, Therefore, using a simple mechanism model to present the basic laws of building heat transfer, Then, the actual detection data is used to calibrate the model parameters online, Finally, we can get the digital twin of the building heat load; next, In a real-world environment, Master the actual measurement value of the indoor temperature and the given control strategy, Looking at the boundary conditions of the twin body, Building heat load can be accurately predicted in a short time; last, Using the model prediction and control idea, Select the best heat pump boot control strategy. In the process of experimental analysis, the physical model is used to combine the actual measurement data of the previous day, and the particle full algorithm is used for rolling optimization, so as to complete the prediction analysis. In this process, the digital twin can use the real-time collected running data for automatic evolution update, and finally get the correction results as shown in Table 2 below:Table 2corrected the results

Date	Length of building	Building height	Building width	Indoor air density	Number of Windows	Window thickness
2023.8.21	315.71060	70.997	12.9532	19.0416	6000	0.0449
2023.9.21	314.9964	71.998	12.9232	20.1622	6000.1	0.0449

Combined with the analysis of the above figure, it can be seen that there is little difference between the actual measured indoor temperature change and the simulated indoor temperature change. The twin whose parameters are constantly updated according to the actual measurement data can complete the prediction analysis with high accuracy in a short time. In this context, the idea of model predictive control is used to determine different heat pump startup decisions, and the indoor temperature evolution trajectory in the future can be independently deduced according to the digital twin technology. The most economical heat pump startup decisions can be found to ensure that the indoor temperature is within the given standard, so as to obtain the most suitable control strategy for cooling and heating systems.

3.2 Future Outlook

The concept of digital twin has been spread rapidly under the background of information technology, which has brought abundant opportunities for technological innovation in the field of electric power in the new era. Now, China is in an important stage of low-carbon development, the power industry in the industrial upgrading and technological innovation at the same time, the relevant technical requirements and development goals are getting higher and higher, so how to fully promote the green low-carbon transformation and development in the background, truly achieve technological innovation driven, actively create a digital twin power grid system, to achieve dual carbon development goals, It is the main problem comprehensively discussed in the electric

power industry at present. The application of digital twin in the field of power grid is more and more rich, especially in the rapid development of new technologies such as cloud computing, artificial intelligence, big data, etc., the construction and application of digital twin computer has achieved excellent results, and the future digital twin power grid will develop in the direction of generalization, intelligence and systemization. For example, every mechanical equipment and part contained in the future power grid system will have its corresponding digital twin, and it will be used throughout the life cycle management to meet the needs of power enterprises for fine business management; In the future, the digital twin power grid system will break the original fragmented construction and application mode, organically integrate the digital twins of all devices together, and accurately grasp the implementation status and development trend of the power grid system operation after building the digital twin system of the entire power grid. With the construction and development of digital twin cities and digital twin power grids, the full integration of the two has become an inevitable trend of the reform and technological innovation of The Times. The digital twin power grid system has strong open characteristics, and can cross-integrate with transportation, construction and water and other fields to provide technical support for the construction of smart cities with Chinese characteristics.

Conclusion

To sum up, energy reform and technological innovation have made the digital and intelligent transformation and upgrading of the power industry an inevitable trend of development. Applying the theory of digital twin technology to the construction and management of power system, changing the functional form and production management mode of traditional power energy, actively cultivating more excellent technical talents, and actively demonstrating the application value of advanced technology theory can not only accelerate the pace of digital transformation of future power enterprises, but also drive the upstream and downstream development of the industrial chain. In this way, the development goal of carbon peak and carbon neutrality can be achieved.

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